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and especially if the mercurial surface is in the form of a narrow strip about $\frac{1}{8}$ th of an inch wide, strong vibrations occur ; and symmetrical crisspations of singular beauty, accompanied by definite sounds, are produced at the mutual surfaces of the liquid metal and electrolyte.

In my experiments the crisspations and sounds were readily produced by taking a circular pool of mercury from 1 to 3 inches in diameter, surrounded by a ring of mercury about $\frac{1}{8}$ th or $\frac{1}{16}$ th of an inch wide, both being contained in a circular vessel of glass or gutta percha, covering the liquid metal to a depth of about $\frac{1}{2}$ an inch with a rather strong aqueous solution of cyanide of potassium, connecting the pool of mercury by a platinum wire with the positive pole of a battery capable of forcing a rather large quantity of electricity through the liquid, and connecting the ring of mercury with the negative platinum wire. The ring of mercury immediately became covered with crisspations or elevated sharp ridges about $\frac{1}{16}$ th of an inch asunder, all radiating towards the centre of the vessel, and a definite or musical sound was produced capable of being heard, on some occasions, at a distance of about 40 or 50 feet. The vibrations and sounds ceased after a short time, but were always reproduced by reversing the direction of the electric current for a short time, and then restoring it to its original direction. The loudness of the sound depends greatly upon the power of the battery ; if the battery was too strong the sounds did not occur. The battery I have used consists of 10 pairs of Smee's elements, each silver plate containing about 90 square inches of immersed or acting surface ; and I have used with equal success six Grove's batteries, arranged either as 2 or 3 pairs, each platinum plate being 6 inches long and 4 inches wide. If the cyanide solution was too strong, the sounds were altogether prevented.

Being occupied in investigating the conditions and relations of this phenomenon with the intention of submitting a complete account of the results to the notice of the Royal Society, I refrain from stating further particulars on the present occasion.

April 18, 1861.

Major-General SABINE, R.A., Treasurer and Vice-President,
in the Chair.

The following communication was read :—

“On the Effect produced on the Deviation of the Compass by the Length and Arrangement of the Compass Needles; and on a New Mode of correcting the Quadrantal Deviation.” By ARCHIBALD SMITH, Esq., M.A., F.R.S., late Fellow of Trinity College, Cambridge; and FREDERICK JOHN EVANS, Esq., R.N., Superintendent of the Compass Department of Her Majesty’s Navy. Received April 13, 1861.

(Abstract.)

When the length of the compass needle may be neglected compared with the distance of the iron which acts on a ship’s compass, the deviation is accurately expressed by the formula

$\sin \delta = A \cos \delta + B \sin \zeta' + C \cos \zeta' + D \sin (\zeta + \zeta') + E \cos (\zeta + \zeta')$; in which ζ is the azimuth of the ship’s head measured *eastward* from the *correct magnetic north* ;

ζ' is the same azimuth, but measured from the direction of the *disturbed needle* ;

$\delta = \zeta - \zeta'$ is the *easterly deviation* of the needle ;

A, D, E are coefficients depending on the distribution of the soft iron of the ship.

B and C are coefficients depending partly on the distribution of the hard and soft iron of the ship, and partly on the magnetic dip and horizontal force at the place.

In all ships which have been examined, A and E are so small that they may be neglected ; and, if the deviation be of such an amount that we may take δ for $\sin \delta$,

$$\delta = B \sin \zeta' + C \cos \zeta' + D \sin (\zeta + \zeta').$$

The first two terms represent the “Semicircular” deviation, the last term the “Quadrantal” deviation.

The “semicircular” deviation is, on the plan proposed by the Astronomer Royal, and extensively practised in the mercantile marine, corrected by magnets ; the “quadrantal” by masses of soft iron placed on each side and at the same level as the compass ; and when the distance of the correction is sufficiently great, this correction may be considered as perfect for the time and place at which it is made ; but when this is not the case, errors are introduced, which it is the object of the paper to consider.

Mr. Evans observed that the standard compass of the ‘Great

Eastern,' which had been corrected on Mr. Airy's plan by Mr. Gray of Liverpool, had errors of between 5° and 6° on some points. It occurred to him that this error was caused by the length of the needle and the proximity of the correctors, and to test this he made experiments on the deviation produced on needles of different length by magnets and soft iron with the following results.

With 3-inch single needles deflected by magnets, the deviations were nearly "semicircular;" but with 6-inch needles, and still more strongly with 12-inch needles, a "sextantal" error of very considerable magnitude was introduced.

With soft iron correctors deflecting a $7\frac{1}{2}$ -inch single needle, in addition to the "quadrantal" deviation, a considerable "octantal" error was introduced.

When the same experiments were made with an Admiralty standard compass card, constructed as usual with four parallel needles, the extremities of which are 15° and 45° on each side of the extremities of the diameter to which they are parallel, *there was no appreciable sextantal or octantal deviation*. And on investigating the subject mathematically, it appeared that *this arrangement of needles, or the simpler arrangement of two needles each 30° on each side of the diameter, produces a complete compensation and correction of these errors*.

The formulæ are the following :—The deviation produced in a single needle of length $2a$ by a magnetic particle M at the same level and at a distance b , is

$$\frac{M}{b^2} \cdot \frac{1}{H} \left\{ \left(1 + \frac{3}{8} \frac{a^2}{b^2} \right) \sin \zeta' + \frac{15}{8} \frac{a^2}{b^2} \sin 3 \zeta' \right\},$$

giving a sextantal deviation bearing to the semicircular proportion of

$$\frac{15}{8} \frac{a^2}{b^2} : 1 + \frac{3}{8} \frac{a^2}{b^2}.$$

If the compass has two needles the ends of each a° from the ends of a diameter, the deviation is

$$\frac{M}{b^2} \cdot \frac{1}{H} \left\{ \left(1 + \frac{3}{8} \frac{a^2}{b^2} \right) \sin \zeta' + \frac{15}{8} \cdot \frac{a^2 \cos 3 a}{b^2 \cos a} \cdot \sin 3 \zeta' \right\}.$$

So that if $a=30^\circ$, or if the two needles be each 30° on each side of the diameter which is parallel to them, the sextantal term disappears.

If we have four needles the ends of each pair a° and a'° from the ends of a diameter, the sextantal term has a factor,

$$\cos 3 \frac{a+a'}{2}.$$

Showing that if, as in the Admiralty compass, the needles of each pair are placed at equal distances on each side of the lines of 30° , the sextantal deviation will be reduced to zero.

A similar investigation shows that the same arrangement of needles reduces to zero the octantal error introduced by the too great proximity of the soft iron ; and further, the error introduced by the magnetism of the needle inducing magnetism in the soft iron in its vicinity.

The conclusion of the authors is that by the use of the Admiralty standard compass, or of a compass with two needles each 30° from the diameter parallel to them, the correcting magnets and soft iron correctors may be placed much nearer the compass than can safely be done with a single needle compass card, and the large deviations found in iron ships far more accurately corrected.

Correction of the Quadrantal Deviation.—It has long been known that two compasses placed as in the common double binnacle, produce in each other a *negative* quadrantal deviation. The discussion by Mr. Evans of the deviations of all the iron-built ships in the Royal Navy (Phil. Trans. 1860, p. 337), showed that the quadrantal deviation in such ships is always *positive* ; and as there is great difficulty and inconvenience in the usual mode of correcting large quadrantal deviation by soft iron, it occurred to Mr. Evans that the correction might be made by the reciprocal action of two compasses placed at the distance of 18 to 24 inches from each other, as in the common double binnacle. The precautions to be used are that the two compasses must be of equal power, and as the correction is inversely as the earth's horizontal force at the place, if great accuracy is required there ought to be the means of adjusting the distance of the two compasses, and the method will probably be found inapplicable in very high magnetic latitudes.

The deflection so produced by one compound compass on a like compass is

$$-\frac{3M}{b^2} \frac{1}{H} a \cos a \left\{ \left(1 + \frac{5}{3} \frac{a^2}{b^2} \cos^2 a \right) \sin 2 \zeta' - \frac{35}{b} \frac{a^2}{b^2} \frac{\cos 3 a}{\cos a} \sin 4 \zeta' \right\}.$$

In this arrangement therefore an octantal error is introduced which may be avoided by the use of two Admiralty standard cards, or cards with two needles each 30° from the diameter which is parallel to them.